Image Calibration and Deconvolution for Space Object Imaging

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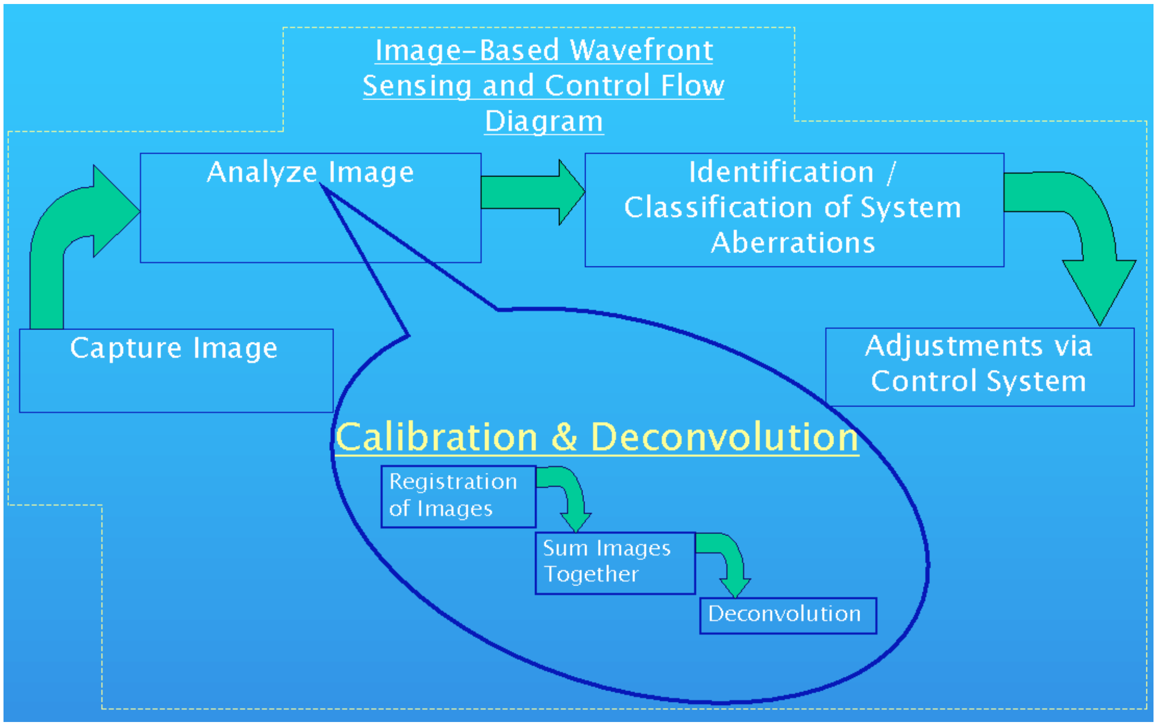
Abstract:

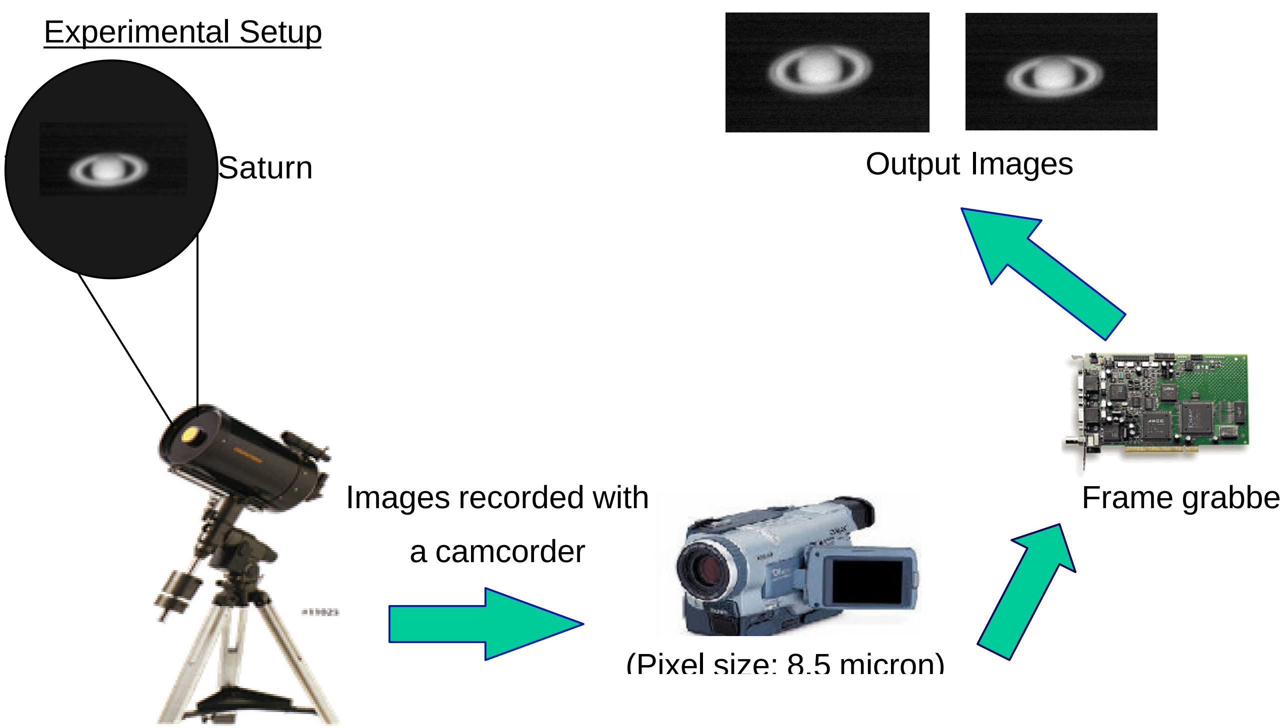
Data was collected using a 12" Schmidt-Cassegrain telescope with off-the-shelf imaging equipment. The data was then recorded using a home video recorder and the individual frames were captured from mini-DV tape. Video and CCD imaging systems can produce short-exposure images that contain little or no information due to poor SNR (signal-noise-ratio), blurring due to object motion, atmospheric turbulence, or optical system mis-alignments. Each of the listed aberrations can be corrected to some degree and faults within the optical system can be estimated using image calibration and deconvolution techniques.

Introduction

Testing the optical system can be achieved via analysis and repair of resultant images by means of calibration and deconvolution algorithms/filters. This can be used as one approach to Image-based wavefront sensing and control.

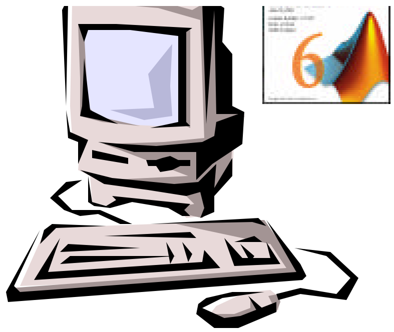


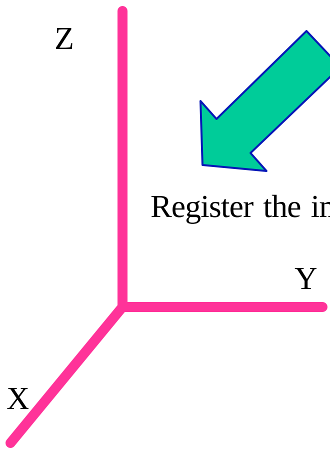
Experimental Setup



Analysis Methods and Tools

MATLAB Development Environment



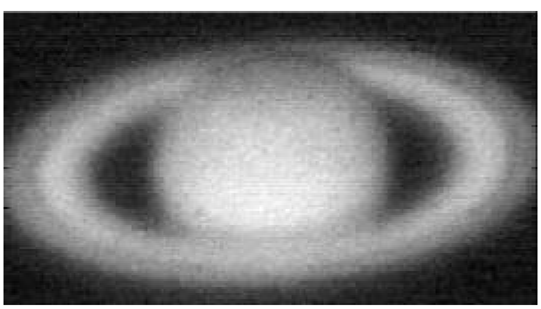


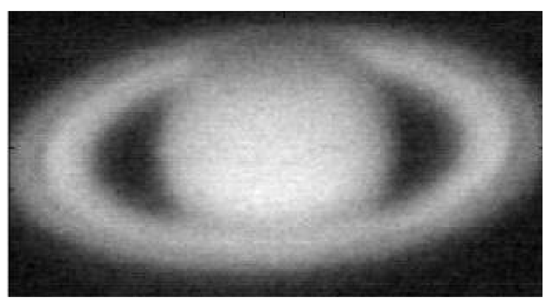
Register the image

Deconvolve registered image

$$f(E) = \int_{-\infty}^{\infty} g(x)\,h(E - x)\,dx$$

Sample Data Frames

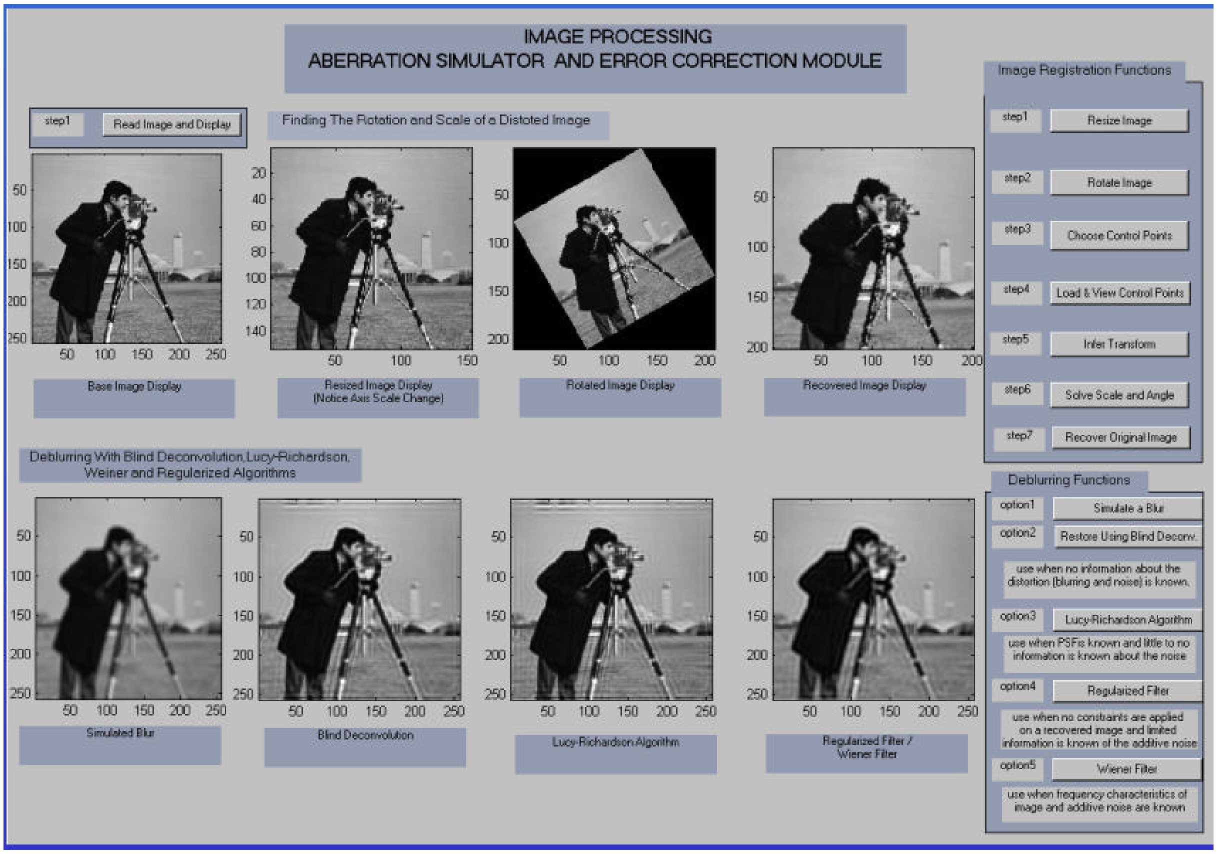




Personal Contribution

Development/Testing of Calibration and Deconvolution Techniques
Development of a Graphical User Interface for Image Processing

Graphical User Interface



General Filter Derivation

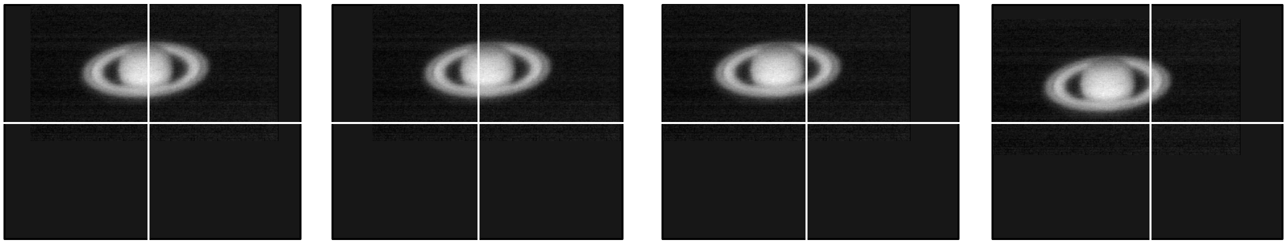
$$i_d = psf_d \otimes i_o + n, \qquad \Im(i_d) = I_d = PSF \cdot I_o + N, \qquad I_o' = Y \cdot I_d$$

$$\text{minimize: } e^2 = \left\langle \left| I_o - I_o' \right|^2 \right\rangle, \ \frac{\partial}{\partial \bar{\bar{Y}}}(e^2) = 0, \ \Rightarrow \ Y = \frac{PSF}{PSF^2 + (S_N / S_O)}$$

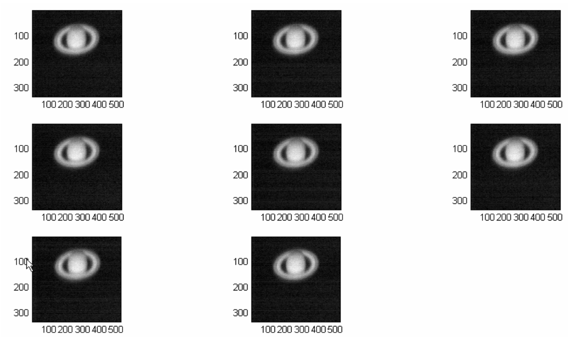
$$\text{Case1}: \frac{S_N}{S_O} \ll 1, I_o = \frac{I_d}{PSF} \qquad \text{Case2}: \frac{S_N}{S_O} \gg 1, \ Y \to 0$$

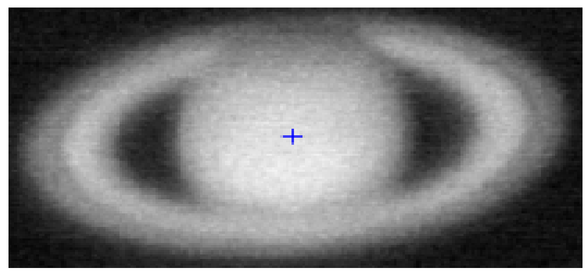
Results and Conclusions

Sample Raw Data From Frame Grabber:



Calibrated Images:

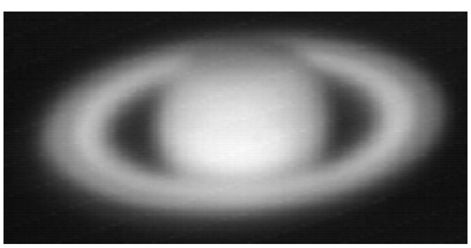


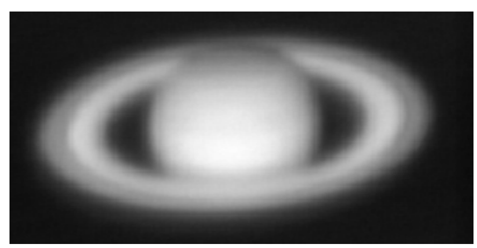


(Registration by hand)

(Registration via centroiding)

Summed Images:

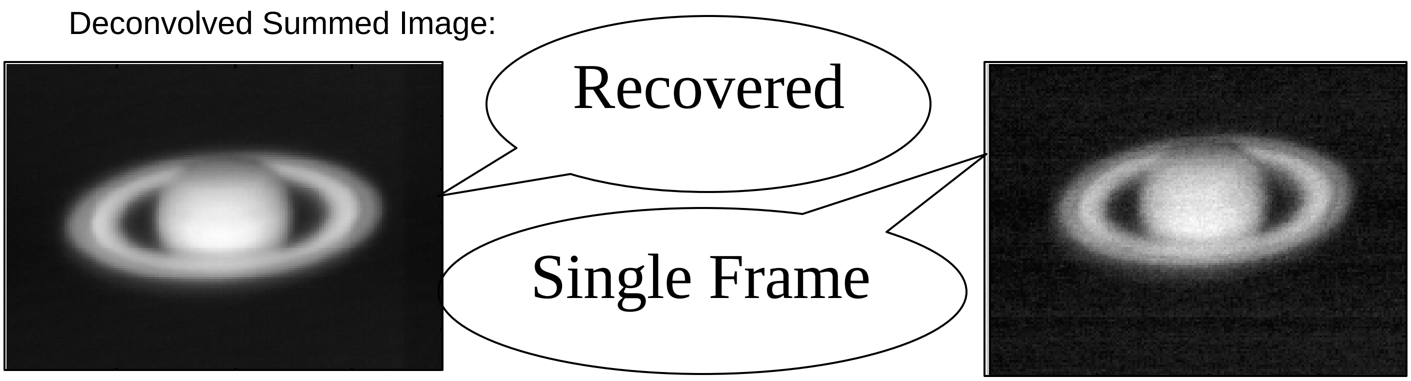




(No centroiding)

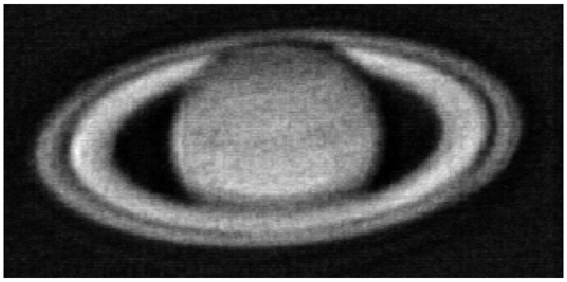
(Centroid (tol:0.05) +Sum)

Deconvolved Summed Image:

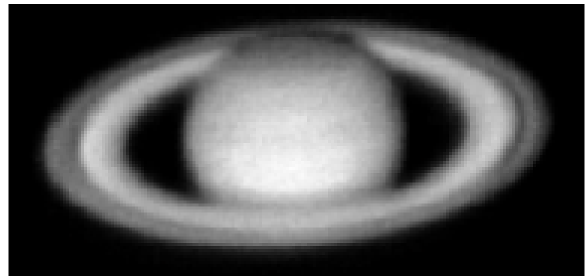


MATLAB Blind Deconvolution

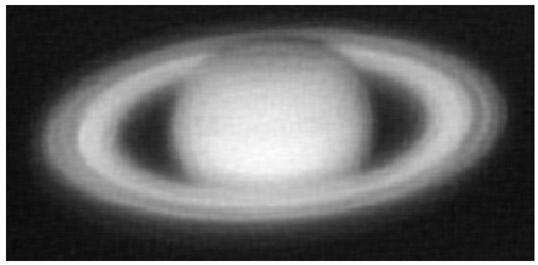
Alternative Approaches:



1



2



3

•Register, Deconvolve and Sum (1&2): Custom Ayers-Dainty Algorithm
•MATLAB: Deconvolve, Register and Sum (3)

In conclusion, calibration and deconvolution techniques can greatly improve image quality. In addition, resulting information can be used to characterize the optical system.